JAMES CLERK MAXWELL (*continued*)

He wrote a certain amount of flippant verse about this time, of which I hope I may be pardoned if I reproduce two specimens of a mathematical kind.

RIGID BODY SINGS

Gin a body meet a body
Flying through the air,
Gin a body hit a body,
Will it fly ? and where ?
Ilka impact has its measure,
Ne'er a ane hae I,
Yet a' the lads they measure me,
Or at least they try.

Gin a body meet a body
Altogether free,
How they travel afterwards
We do not always see.
Ilka problem has its method
By analytics high.
For me I ken na ane o' them,
But what the waur am I ?

Or the even better one, where a most unpromising mathematical problem has been turned, if not into poetry, at any rate into verse. Here is the statement of the problem.

An inextensible heavy chain
Lies on a smooth horizontal plane,
An impulsive tug is applied at A
Required the initial motion of K.
Let ds be the infinitesimal link
Of which at present we 've only to think.
Let T be the tension, and $T+dT$
The same for the end that is nearest to B.
Let a be put by a common convention
For the angle at M 'twixt OX and the tension ;
Let Vt and Vn be ds's velocities,
Of which Vt along and Vn across it is :
Then Vn/Vt the tangent will equal,
Of the angle of starting worked out in the sequel.

He is remembered for at least two investigations on cats. He investigated the rapidity with which a cat could turn round when let drop upside down so as to alight on its feet. I forget his conclusion, but think it was of the order of six inches. The other conclusion has a dynamical flavour. Going into a room one day with some friends, he saw a black cat jump out of the window, some twenty feet from the ground. Going forward to the window, he looked out; but the cat had vanished, and there seemed no place where it might have gone. The matter remained a mystery till Maxwell propounded the solution. On falling from the window, the black cat going down must have met an equal and opposite white cat coming up. These had neutralised each other. Result—no cat.

But, as Maxwell says : " All things are full of jokes, but that does not hinder them being full of seriousness." Despite the illustrations I have given of his levity, he was one of the most intensely serious of men. In addition to being a mathematical genius of the highest rank, there was in him a strain of mysticism to which philosophy and religion made a deep appeal, and which forms a side of his character which no one who talks of him can neglect.

This interest in metaphysics was a side of his character that deeply impressed Maxwell's friends. Even at this distance of time one is impressed with the unity Maxwell made of his life. His philosophy and religion were combined with his mathematics and with his whole character. A more than usually intelligible fragment may indicate that this kind of thought was not an excrescence, but was always passing through his mind, even when engaged at other work. Thus he writes in his letters somewhere : " The true logic of this world is the calculus of probabilities, which takes into account the magnitude of the probability which is, or ought to be, in a reasonable man's mind. This branch of mathematics, which is generally thought to favour gambling, dicing, and wagering, and therefore highly immoral, is the only " mathematics for practical men," as we ought to be. What is believing ? When the probability—there is no better word found—in a man's mind of a certain proposition being true is greater than that of its being false, he believes it with a proportion of faith corresponding to the probability, and this probability may be increased or diminished by new facts. This is faith in general. When a man thinks that he has enough of evidence for some notion of his, he sometimes refuses to listen to any additional evidence pro or con, saying : ' It is a settled question : *probatis probata*. It needs no evidence. It is certain.' This is knowledge as distinguished from faith. This knowledge is the shutting of one's ears to all inquiries, and is the same as implicit faith in one of its meanings : " Childlike faith " confounded with it is not credulity, for children are not credulous, but find out sooner than some think that some men are liars."

Much of his poetry is tinged with this tendency to a serious view of life. I would like to illustrate it by one poem which is sufficiently beautiful in itself to bear quoting :

Alone on a hillside of heather,
I lay with dark thoughts in my mind.
In the midst of the beautiful weather
I was deaf, I was dumb, I was blind.

I knew not the glories around me,
I counted the world as it seems,
Till a spirit of melody found me
And taught me in visions and dreams.

For the sound of a chorus of voices
Came gathering up from below,
And I heard how all Nature rejoices
And moves with a musical flow.
O ! strange ! we are lost in delusion,
Our ways and doings are wrong !
We are drowning in wilful confusion
The notes of that wonderful song.

But listen, what harmony holy
Is mingling its notes with our own,
The discord is vanishing slowly,
And melts in that dominant tone.
And they who have heard it can never
Return to confusion again,
Their voices are music for ever,
And join in the mystical strain.

No mortal can utter the beauty
That dwells in the song that they sing :
They move in the pathway of duty,
They follow the steps of their King.
I would barter the world and its glory,
That vision of joy to prolong,
Or to hear and remember the story
That lies in the heart of their song.

He was a good, kind man. His religion was not of a dreamy sort either. In his busiest time, just before an important exam, he gave up an hour a day to make up a friend's bed, and later in life we hear of him breakfasting off porridge in a little back room, the bowl held on his knees owing to difficulties of space. He had given up his room to a sick friend who had come into town for an operation, and Maxwell himself did not sleep in a bed for three weeks. Small wonder, then, that he is remembered for his entire goodness and kindness to every living thing. He " liked to go and stroll in the fields and fraternise with the young frogs and the old water rats." He was a good shot, but was not a sportsman. From his earliest days he could not kill a fly, and he shrank from taking the life of a fellow living creature for fun. He had always been fond of what he called " clean dirt," and as a boy often played with puddocks, taming them to do all sorts of tricks.

Rapidly reviewing his later life : In 1856 his father died, and this, owing to the closeness of the relationship between the two, was a great blow. More especially was this the case as the son had just applied for the Chair of Physics at Marischal College, Aberdeen, with the idea of spending the long summer holiday with the old man at Glenlair. It was when he was at Aberdeen that he married, and what seems to have been a singularly happy and beautiful marriage resulted. He was not a great success as a teacher, for he was too far above many of his listeners' heads for them to grasp his allusiveness. He was doubtless a stimulus to the best students. On the union of the colleges in Aberdeen, he was left without a job. He tried for the Chair at Edinburgh, but it went, quite properly, to his old friend Tait. In 1860 he was appointed to the Chair of Physics at King's College, London, where he stayed till 1865, when he retired owing to a breakdown in health, and he retired to Glenlair to write the great book on Electricity and Magnetism for which in especial he is gratefully remembered. One of the few pictures of him was probably taken about this time, and corresponds to the pen-portrait:—" He was of middle height, with a face full of sagacity and good humour, but with a deep shade of thoughtfulness, dark and glowing eyes. He had a keen sense of humour, but rarely laughed ; a twinkle of the eye was all that showed it. He was not irascible, but placid and patient. He was very neat-handed in his experiments, with a habit of whistling to himself as he worked, and he was capable of working amid the most distracting surroundings."

During a portion of his time at Glenlair he was an examiner for the Cambridge Mathematical Tripos, and was largely responsible for that infusion of new methods and learning which was one of the causes of the foundation of a world-wide School of Physics. Hence, when in 1870, by the munificence of the then Duke of Devonshire, the Cavendish Laboratory was projected, it was felt that no one had such qualification for the post as he had, and he was appointed professor and designer of the laboratory. He speedily gathered round him men of great capacity and attainments, and good work was done from the very start. An incurable illness seized him in 1877, but he stuck to his post till November 1879, when his death took place. He lies buried in good Scots clods in Parton churchyard.

But what is there in all this that gives us grounds for regarding him, not as a great man, but as a very great man ?

This is a difficult task, and I fear that it is quite beyond me to make it clear. I can only put it as simply as I can, and as it appears to me. Let us go for a moment to his early days. From boyhood he was always playing while he worked and working while he played. I do not know if any of you are acquainted with a toy that had a considerable vogue a few years ago—diabolo. That is a survival from Maxwell's early days, when it went by the name of the " devil on two sticks." This toy was a constant occupation of Maxwell's in both his early and earliest years, and he could do almost anything with it. In one of his letters we find him saying : " I can jump over him and bring him round without leaving go

of the sticks. I can also keep him up behind me." Again, we find that at a very early age he made pictures for a zoetrope, that early toy which contains in it the principle of the kinematograph. Further, we find that as a boy he was always trying to illustrate his letters by diagrams or little pictures, and, as we have seen, the construction of apparatus was always a hobby of his.

Now the child is father of the man, and I seem to be able to see that the theories on whose discovery or consolidation his chief claim on the recollection of mankind is based, owed their inception largely to these childish ploys among the Galloway Hills, though of course he was developed and helped by many of the influences which he met with in life, chief among whom I place his father, Dr. Gloag, Lord Kelvin,

Scots Academies
Chune "Green grow the rashes, O!"

If ony here has got an ear
He'd better tak a haud o' me,
Or I'll begin, wi' roarin din,
To praise our old Academy.

Dear old Academy!
Queer old Academy!
A merry lot were we, I wot,
When at our old Academy!

There's some may think me crouse wi' drink,
And some may think it mad o' me,
But ither some will gladly come
And cheer our old Academy.

Some set their hopes on Kings and Popes,
But o the sons of Adam, he
Was first without the smallest doubt
That built the first Academy

Let Pedants seek for scraps o' Greek
Their lingo to Macadamize,
Gie me the sense without pretence
That come o' Scots Academies.
Let scholars all, both great and small,
Of Learning mourn the sad demise
That they may think, but we will drink
"Good luck to Scots Academies."

Autograph Poem by James Clerk Maxwell.

Tait, and Faraday. The devil on two sticks must have been a fruitful source of inspiration in dynamics, besides having somewhat to do with his neathandedness in experimental work, and the colour top and zoetrope of his boyhood developed into the theory of vision of the man.

His contributions to knowledge fall under three main heads:—optics, molecular theory, and electricity.

At the time when Maxwell appeared the physical sciences were in process of transformation from the qualitative to the quantitative stage, and Maxwell was one of the men who had the greatest part in assisting the transformation. Take, for example, his contributions to optics. Here Newton had done great pioneer work, and had given without proof a rule by which the colour of any mixture of what he called the primary colours (VIBGYOR) could be predicted. Maxwell by a mathematical method showed that this involved the statement that only three elements of colour were essential. This theory had also been propounded by Young, whose theory of vision it was, that there are only three primary sensations, which correspond to red, green and violet. Maxwell conducted laborious experiments to see if it were true that any colour could be matched to the eye by a suitable mixture of these three colours, and found that all the colours of the spectrum and therefore all colours in nature could be perfectly imitated to the eye by suitable mixtures of a red, a green, and a violet spectrum colours of wave length 6302, 5281 and 4569 tenth-metres respectively. At first he used the principle of the colour top, but abandoned it in favour of his "colour box," which is based on the principle of what may be called the inverted spectroscope. A beam of white light, as is well known, on passing through a prism is broken up into a spectrum, and this by a suitable arrangement of lenses can be made to fall on a screen in the form of a pure spectrum. If a beam of any coloured light, say red, is made to start from the point on the screen on which it fell and reverse its path, it will fall on the spot from which the original beam of white light diverged. If a beam of white light is made to diverge from this point, only the red will fall on the original source, and the other colours in the white light will fall elsewhere. By putting adjustable slots in the position of his primary colours he was able to make definite proportions of his primary colours fall on one spot, and compare the resulting sensation with the colour he was wishing to match. You will recognise that in addition to their theoretical value, these researches represent the basis of coloured photography and three-colour processes of printing.

The second of his activities was dynamical theory. Besides increasing his dexterity, the pastime of diabolo must have served as the starting point of much thought. It was therefore natural that the subject of the Adam's Prize, the constitution of Saturn's rings, should have attracted him. The mathematical investigation led him to the belief that these rings are not solid, as one might well suppose, but consist of myriads of stony particles—a flight of brickbats, he calls them—for ever rotating round their parent planet and clashing with each other in their progress. This investigation seems to have led in its turn to another of the deep mathematical investigations for which he is gratefully remembered—for his share in placing the kinetic theory of gases on good and solid foundations. Here again, other names must be mentioned as pioneers or helpers—Daniel Bernoulli, Herapath, Joule, Waterston (whose work, preceding that of Maxwell, was not unearthed from the Archives of the Royal Society till a dozen years after Maxwell's death), Clausius, Boltzmann—all these assisted in building up this great theory. Indeed it is not even a recent theory, being suspected in classical times, but in the modern manner deductions have been made from the theory and tested by experiment. Before Maxwell's time it had been shown that the pressure of a gas was proportional to the product of the mass of the molecules, their number, and the square of their average velocity; that is quite simple mathematics. Waterston and Maxwell showed that the mean square of the velocity of the gas molecules gave a measure of the temperature of a gas, and this simple set of assumptions can be shown to be in agreement with the laws of Boyle, Charles, Avogadro, and Graham. Now Clausius had pointed out that a body might have energy of rotation as well as energy of translation. He also took some steps in the calculation of the length of the paths of the molecules between collisions. Maxwell's penetrating intellect now devised the next step. He invented a new method of dealing with problems which have to deal with large quantities of objects, the statistical method. As a result he gives his law of partition of velocities. A further and more difficult investigation gives his law of partition of energy, that the kinetic energy of a system is ultimately divided up equally among the variables that determine a system.

But while this is important, the third and most important of Maxwell's activities was his contribution to electrical theory.

In 1850, when Maxwell was about nineteen and the British Association met in Edinburgh, he had rather astonished the audience by getting up and disputing some point with Sir David Brewster. This seems to have led to an acquaintance with Lord Kelvin, and one can well imagine what impression the older, and till then greater, scientist would have on the young

man. He had, of course, always been interested in electricity. Quite early in his school career, when he was eleven years old, we hear of him being taken to see "the electromagnetic machines," and his interest in galvanism, *i.e.* electricity, at Glenlair is noticeable in all his holiday letters. He was therefore ripe to be influenced by the electrical work of Lord Kelvin. Indeed one of Lord Kelvin's many distinctions is that he was "the inspirer of Clerk Maxwell, his avowed pupil in all important respects, and was thus an essential factor in that consolidation and reconstruction of physical science, on refined electric or sub-electric basis which is still in progress and has been the main glory of the latter half of the nineteenth century." In particular the work of the great experimenter, Faraday, must have impressed him. Faraday had given a general qualitative explanation of the facts, many of which he had himself discovered; Kelvin had given a quantitative explanation of a part of them; but Maxwell worked out the theory in proper mathematical form, pursued its deductions, and made many far-reaching conclusions, some of which, such as the possibility of wireless telegraphy, have only been verified since his death. Even in his lifetime he showed that the medium which allows light to come to our eyes, and the medium which allows electromagnetic phenomena to occur in it are the same. (That some mathematicians now reject the idea of the ether seems to matter less to ordinary men than it might, as the properties of the ether seem to have been transferred to the idea of space, and we have a physical analogue to that wise boy's statement of the Homeric controversy: "Some people think that these poems were not written by Homer, but by another man of the same name.") Thus he showed that light was an electromagnetic phenomenon. The methods are not such as to admit of popular explanation. Even talented people find them difficult to understand, still more to explain. Earlier, we have seen that one striking fact about Maxwell is the success with which he unified his own life. So to put the matter of Maxwell's supreme achievement in a popular if rather inaccurate manner, he has presented a picture which helps to show that the world is one. He has shown that light, electricity, and all the effects that are supposed to act at a distance, with the possible inclusion of gravity itself require only one ether. In addition his work has been the inspiration of another world-wide genius, stimulating the latter to complete the story and give the world the upsetting, but apparently correct, theory known as relativity.

Now, was Maxwell a very great man, or only a great man? The evidence of one eminent man has been given. Consider in conclusion the evidence of others competent to give an opinion.

I am permitted by the Rector to quote from a letter he has received from Professor Sir A. S. Eddington, from the Observatory at Cambridge.

"Some years ago I went into Einstein's study in Berlin, and saw that on the walls there were just three portraits—Newton, Maxwell, and Faraday. My own selection would be the same, except that to get in Einstein I would have to squeeze out Faraday. Your former Academy boy was famous in his lifetime, but his genius is far more appreciated now."

To squeeze out Faraday! Not a word of Kelvin, Tait, Helmholtz, and these other giants of the nineteenth century! And they *were* giants. Surely an overwhelming tribute.

Or lastly, hear a considered judgment by Professor Schuster in his book, *Britain's Heritage of Science*: "Every one interested in the history of Science must often have asked himself the question how far its progress would have been retarded if a particular brain had never been called into existence. With few exceptions the answer would be, that though discoveries might have been delayed, and reached by different roads, and the work of one man divided between two or three, the effect in the long run would have been small and perhaps insignificant; but it is difficult to believe that science would stand where it does to-day, if Maxwell had never lived. Maxwell's originality of thought was the essential factor in the investigation, and it is almost impossible to see how his results could have been arrived at by a different road than that he took.

"In formulating the essential properties of the medium which could produce the electrical effects, Maxwell had to fit a mathematical mantle on the somewhat crude skeleton of Faraday's creation. The task was formidable, and the manner in which it was carried through stands unequalled by any achievement in the whole range of scientific history, both as regards its intellectual effort and its final result."

And it is of the work of an Academy boy that he is speaking. Surely we are right to be proud of him.

M. M'C. F.

"IOLANTHE"

THE Musical Society's performance of this delightful opera on 5th June was in almost all respects successful, and in some charming. A not unnatural premonition that the Fairies would prove to be a boot-y rather than a beauty chorus proved to be unfounded, and I lost my heart to several members of a band of remarkably competent Peris.

The Peers' entering chorus was rendered with appropriately pompous humour, and I felicitate the